

REMARKS/ARGUMENTS

Claims 1-8 are pending in the application. Claims 9-20 were previously canceled without prejudice. No claims are amended. A listing of claims, although not required, is included for the Office's convenience. Reexamination and reconsideration of the application, as amended, are respectfully requested.

Claim Rejections – 35 U.S.C. § 103(a)

Claims 1-8 stand rejected under 35 U.S.C. 103(a) as anticipated by Möller (Multicrystalline Silicon for Solar Cells, Solid State Phenomena, 1996,47-48, page 124-142) in view of Saito (US 2004/0067647) and further in view of Ishihara (US 2006/00676470) Applicant respectfully traverses the rejection.

Claim 1 of the present application is as follows:

A polycrystalline silicon substrate for use in a photoelectric conversion element, comprising a region which contains concentrations of impurities that satisfy the following relations:

$[O_i] \geq 2E17$ [atoms/cm³] (Condition 1a) and

$[C] \leq E17$ [atoms/cm³] (Condition 2)

where $[O_i]$ is an interstitial oxygen concentration determined by Fourier transform infrared spectroscopy and $[C]$ is a total carbon concentration determined by secondary ion mass spectrometry;

wherein the polycrystalline silicon substrate is doped with boron.

Applicant respectfully submits that claim 1 is not obvious in view of the cited art because the differences between the claimed invention and the cited art would not have been obvious to a person of ordinary skill in the art at the time the invention was made. Specifically, Applicant respectfully submits that it would not

have been obvious to a person of ordinary skill in the art to make polycrystalline silicon substrate for use in a photoelectric conversion element having a total carbon concentration $[C] \leq E17$ [atoms/cm³], wherein $[C]$ is a total carbon concentration determined by secondary ion mass spectrometry (SIMS).

Importantly, the instant claims require that the total carbon concentration $[C]$ be measured by the SIMS technique. The total carbon concentration, $[C]$, measured by the SIMS technique is a sum of interstitial carbon concentration $[Cs]$ and precipitated carbon concentration, $[\angle C]$.

The examiner cites Möller, Figure 10(b) for the teaching silicon substrates that have $[C] \leq E17$ [atoms/cm³]. However, the concentration of carbon in Figure 10(b) is measured by FTIR, which Möller admits "yields the dissolved species only." Möller, Figure 10(b) thus does not include any precipitated carbon. The Office, however, interprets Möller at p. 3 of the Office Action as teaching that there are small or no carbon precipitates:

"Möller teaches that there is either small or no precipitates formed at all because of the low diffusion coefficients of oxygen and carbon in solid silicon." (p. 133, 3rd Para., page 136 1st para. Last 6 lines) which suggests that total carbon concentration is close to the carbon concentration shown in Fig. 10(b)."

Applicant respectfully disagrees with this interpretation. Möller, at p. 133, under the section entitled "Precipitates," clearly teaches that SiC precipitates in the grain boundaries. These precipitates are greater than 10 nm, as measured by TEM and can be formed in the melt during the production of silicon ingot:

"Occasionally, if the concentrations of carbon and nitrogen in the melt are higher large [sic] SiC and Si₃N₄ precipitates can be observed (Figure 8)...Considering the large diameters it is obvious that the precipitates could only have been formed in the melt where the

diffusion coefficients are much higher compared to the solid. It has been proposed that the nucleation in this case occurs at the melt interface [7]."

Thus, Möller teaches that significant SiC precipitates can form during the melt, which are subsequently still present in the solid ingot. Möller, Figure 8(a), shows a clear example of one such SiC precipitate at a grain boundary as shown by TEM imaging.

In the "Precipitates" section, a p. 133, Möller then contrasts the significant SiC precipitates formed in the melt with the observation that SiC precipitates are not likely to be formed in the solid: "There is however no indication from TEM investigations that SiO₂ or SiC precipitates nucleate and grow in the solid. As will be discussed later the growth of these precipitates is indeed difficult because of the low diffusion coefficients of oxygen and carbon in the solid silicon."

Thus, contrary to the Office's reading, Möller does teach that there are or can be significant SiC precipitates. The section cited by the Office only suggests that the precipitates are not likely formed in the solid, but in the melt. See also, Möller, at p. 136, "The larger SiC precipitates that are occasionally observed have already been formed in the melt, as discussed in the previous chapter." The Office's reliance on Figure 10(b) is inapposite. Möller admits that the concentrations shown in 10(b) are determined by FTIR, which "yields the dissolved species only." Thus, the Office's contention that Möller necessarily yields total carbon concentration as measured by SIMS in the range of Figure 10(b) is not warranted because it does not include the SiC precipitates identified in Möller.

Finally, the Office argues that "it would have been obvious for one of ordinary skill in the art to at the time of the invention filed [*sic*] to adopt a proper impurities level including carbon concentration level as recited in the instant claims for a desired polycrystalline silicon used in solar cell applications (page 138 Electrical

properties section)." However, as has been shown, Möller teaches that significant SiC precipitates may be formed during melt. However, Möller does not teach or suggest how to eliminate SiC precipitates during the melt process. Nor has the office identified any prior art teaching on how to eliminate SiC precipitates during the melt or how such knowledge was within the knowledge of those of ordinary skill. Rather, it is applicant's own specification which provides the necessary teaching.

Applicant also submits that Möller teaches away from the invention of claim 1. Claim 1 requires an interstitial oxygen concentration, $[O_i] \geq 2E17$ [atoms/cm³], as measured by FTIR. However, as shown in Figure 15(b), the lifetime of Cz-silicon decreases at concentrations over $2E17$. Further, since $[O_i] \geq 2E17$ and $[C] \leq E17$, the difference is at least $E17$ (which corresponds to 2 ppma). As shown in Figure 10(a), the diffusion length is lowered if Co-Cc is less than 2 ppma, which causes lower optical conversion efficiency. As such, a person of ordinary skill in the art would not have been motivated to control the levels of interstitial oxygen as measured by FTIR and total carbon as measured by SIMS such that $[O_i] \geq 2E17$ and $[C] \leq E17$ as required by the present invention as Möller suggests these would lead to shorter lifetime and lower conversion efficiency.

Saito and Ishihara are cited by the Office for the teaching of boron doping, and are not cited for their teaching of controlling the interstitial oxygen and total carbon concentration as in the presently claimed invention.

For these reasons, Applicant respectfully submits that the combined cited art does not render the invention unpatentable as being obvious. Withdrawal of the rejection and allowance of claim 1 is respectfully requested.

Claims 2 and 3 depend from claim 1 and are patentable for at least the same reasons as Claim 1. Claim 7 is directed to a polycrystalline silicon ingot for use in a photoelectric conversion element, comprising a region which contains concentration $[C] \leq E17$ [atoms/cm³] wherein $[C]$ is a total carbon concentration determined by

secondary ion mass spectrometry. As such, claim 7 is patentable for at least the same reasons as claim 1. Withdrawal of the rejection and allowance of claim 2, 3 and 7 is respectfully requested.

Claim 4 of the present invention is as follows:

A polycrystalline silicon substrate for use in a photoelectric conversion element, comprising a region which contains concentrations of impurities that satisfy the following relations:

$[O_i] + 30 \times [N] \geq 2E17$ [atoms/cm³] (Condition 1b) and

$[C] \leq 1E17$ [atoms/cm³] (Condition 2)

wherein $[O_i]$ is an interstitial oxygen concentration determined by Fourier transform infrared spectroscopy, $[N]$ is a total nitrogen concentration determined by second ion mass spectrometry, and $[C]$ is a total carbon concentration determined by secondary ion mass spectrometry;

wherein the polycrystalline silicon substrate is doped with boron.

As with claim 1, Applicant respectfully submits that claim 4 is not obvious in view of the cited art because the differences between the claimed invention and the cited art would not have been obvious to a person of ordinary skill in the art at the time the invention was made. Specifically, Applicant respectfully submits that it would not have been obvious to a person of ordinary skill in the art to make polycrystalline silicon substrate for use in a photoelectric conversion element having a total carbon concentration $[C] \leq 1E17$ [atoms/cm³], wherein $[C]$ is a total carbon concentration determined by secondary ion mass spectrometry (SIMS). As such claim 4 is patentable for analogous reasons to claim 1. Withdrawal of the rejection and allowance of claim 4 is respectfully requested.

Claims 5 and 6 depend from claim 4 and are patentable for at least the same reasons as claim 4. Withdrawal of the rejection and allowance of claims 5 and 6 is respectfully requested. Claim 8 contains analogous limitations as claim 4 and is patentable for at least the same reasons as claim 4. Withdrawal of the rejection and allowance of claim 8 is respectfully requested.

Applicant believes the foregoing amendments comply with requirements of form and thus may be admitted under 37 C.F.R. § 1.116(b). Alternatively, if these amendments are deemed to touch the merits, admission is requested under 37 C.F.R. § 1.116(c). In this connection, these amendments were not earlier presented because they are in response to the matters pointed out for the first time in the Final Office Action.

Lastly, admission is requested under 37 C.F.R. § 1.116(b) as presenting rejected claims in better form for consideration on appeal.

In view of the foregoing, it is respectfully submitted that the application is in condition for allowance. Reexamination and reconsideration of the application, as amended, are requested.

If for any reason the Examiner finds the application other than in condition for allowance, the Examiner is requested to call the undersigned attorney at the Los Angeles, California telephone number (310) 595-3107 to discuss the steps necessary for placing the application in condition for allowance.

Appl. No.11/910,217
Amdt. Dated October 29, 2010
Reply to Final Office Action of July 30, 2010

Attorney Docket No. 374611-000087
Customer No. 73230

If there are any fees due in connection with the filing of this response, please charge the fees to our Deposit Account No. 07-1896.

Respectfully submitted,

DLA PIPER LLP (US)

Date: October 29, 2010

By: 

Lawrence J. McClure

Registration No. 44,228

Attorney for Applicant(s)

1999 Avenue of the Stars, Suite 400
Los Angeles, California 90067
Telephone: 310-595-3000
Facsimile: 310-595-3400